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Driving factors of aggregate CO_2 emissions in China

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Abstract

Based on a new production-theoretical decomposition analysis (PDA), this paper decomposes the changes of carbon dioxide emissions in China's provinces into seven drivers. This study finds that economic development, energy structure and energy efficiency are positive driving factors of carbon dioxide emission increase; technological advance, reduction in energy intensity and improvements of carbon dioxide emission efficiency are the negative driving factors; the east, central and west have significant variation on CO_2 changes and some decomposition parts.

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Keywords: carbon dioxide; driving factors; PDA; DEA

Introduction

In order to fulfill the international responsibility for greenhouse gas emissions reduction, as well as to alleviate a series of environmental troubles resulting from carbon dioxide emissions, Chinese government has tried to transform to a low-carbon and sustainable development country by taking a series of policy measures. In recent years, to assess the driving factors of carbon dioxide emissions has become a vital theoretical problem. As for the approaches to decompose carbon dioxide emissions, there are mainly two categories, i.e., index decomposition analysis (IDA) and structural decomposition analysis (SDA). Generally, IDA shows the function of index analysis, this approach can decompose aggregate carbon dioxide emissions or carbon dioxide intensity into economy effect, structure effect, population effect and so on (Ang and Zhang, 2000). The SDA approach is based on the input-output model to analyze the direct or indirect effects that the production departments have on carbon dioxide emissions. The early empirical research based on IDA and SDA is mainly aimed at the main departments of carbon dioxide emissions (Kwon, 2005). In addition to the IDA and SDA approaches, a new decomposition analysis based on the

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production theory (PDA) gains growing attention due to its stronger explanation of carbon dioxide emissions changes recently(Zhou and Ang, 2008; Zhang et al., 2012).

Methodology

The PDA approach utilized distance functions of undesirable output (CO_2 emissions) and input (energy consumption) to decompose the change in aggregated CO_2 emissions over time. This method assumes that N peer provinces use energy consumption (E) to produce gross domestic product (Y) and emit CO_2 (C). The change in aggregated CO_2 emissions for province k can be estimated as the geometric mean between period 0 and T (Zhou and Ang, 2008), as follows:

$$
\begin{aligned}
D_k &= \frac{C_k^T}{C_k^0} = \left(\frac{C_k^T/E_k^T}{C_k^0/E_k^0}\right) \times \left(\frac{E_k^T/Y_k^T}{E_k^0/Y_k^0}\right) \times \left(\frac{Y_k^T}{Y_k^0}\right) \\
&= \left(\frac{\left\{C_k^T\Big/\left[D_c^0\left(E_k^T,Y_k^T,C_k^T\right)D_c^T\left(E_k^T,Y_k^T,C_k^T\right)\right]^{1/2}\right\}\times\left(1/E_k^T\right)}{\left\{C_k^0\Big/\left[D_c^0\left(E_k^0,Y_k^0,C_k^0\right)D_c^T\left(E_k^0,Y_k^0,C_k^0\right)\right]^{1/2}\right\}\times\left(1/E_k^0\right)}\right) \\
&\times \left(\frac{\left\{E_k^T\Big/\left[D_e^0\left(E_k^T,Y_k^T,C_k^T\right)D_e^T\left(E_k^T,Y_k^T,C_k^T\right)\right]^{1/2}\right\}\times\left(1/Y_k^T\right)}{\left\{E_k^0\Big/\left[D_e^0\left(E_k^0,Y_k^0,C_k^0\right)D_e^T\left(E_k^0,Y_k^0,C_k^0\right)\right]^{1/2}\right\}\times\left(1/Y_k^0\right)}\right) \times \left(\frac{Y_k^T}{Y_k^0}\right) \\
&\times \left(\frac{D_c^T\left(E_k^T,Y_k^T,C_k^T\right)}{D_c^0\left(E_k^0,Y_k^0,C_k^0\right)}\right) \times \left(\left[\frac{D_c^0\left(E_k^T,Y_k^T,C_k^T\right)}{D_c^T\left(E_k^T,Y_k^T,C_k^T\right)} \times \frac{D_c^0\left(E_k^0,Y_k^0,C_k^0\right)}{D_c^T\left(E_k^0,Y_k^0,C_k^0\right)}\right]^{1/2}\right) \\
&\times \left(\frac{D_e^T\left(E_k^T,Y_k^T,C_k^T\right)}{D_e^0\left(E_k^0,Y_k^0,C_k^0\right)}\right) \times \left(\left[\frac{D_e^0\left(E_k^T,Y_k^T,C_k^T\right)}{D_e^T\left(E_k^T,Y_k^T,C_k^T\right)} \times \frac{D_e^0\left(E_k^0,Y_k^0,C_k^0\right)}{D_e^T\left(E_k^0,Y_k^0,C_k^0\right)}\right]^{1/2}\right) \\
&= \mathrm{PCFCH}_k \times \mathrm{PEICH}_k \times \mathrm{GDPCH}_k \times \mathrm{CEEFCH}_k \times \mathrm{CATECH}_k \times \mathrm{EUEFCH}_k \times \mathrm{ESTECH}_k
\end{aligned} \tag{1}
$$

The intuitions of the seven items in equation (1) are the potential carbon factor change (PCFCH), potential energy intensity change (PEICH), effect of GDP change (GDPCH), effect of CO_2 emissions technical efficiency change (CEEFCH), shift of CO_2 emissions-side technology or carbon abatement technology (CATECH), effect of energy usage technical efficiency change (EUEFCH), and shift of energy usage-side technology or energy savings technology (ESTECH) for province k. CATECH indicates the technological change of the undesirable output-oriented Malmquist productivity index and ESTECH is the technological change. All the distance functions can be derived by solving the linear programs (2) and (3), where $s,t \in \{0,T\}$, τ, υ and ψ represent the potential input savings, the potential desirable and undesirable output surpluses, respectively, for province k.

Empirical analysis

The proposed methods are applied to illustrate the decomposition of aggregate CO_2 emission changes for thirty provinces in China. The period was from 2005 to 2010.All the data are obtained from the China Statistical Yearbook and China Energy statistical Yearbook. This study uses total energy consumption (in million tons of coal equivalent) as input and produces the real gross domestic product (in RMB billion) and CO_2 emissions (in million tons) are regarded as the desired and undesired outputs, respectively.

$$\begin{aligned} &\left[D_c^s\left(E_k^t,Y_k^t,C_k^t\right)\right]^{-1}=\min\ \theta' \\ &\text{s.t. } \sum_{k=1}^{K} z_k E_k^s \le E_k^t+\tau \\ &\sum_{k=1}^{K} z_k Y_k^s \ge Y_k^t \\ &\sum_{k=1}^{K} z_k C_k^s = \theta' C_k^t \\ &z_k \ge 0,\quad k=1,...,K \\ &s,t\in\{0,T\} \text{ and } s\ne t \end{aligned} \tag{4}$$

$$\begin{aligned} &\left[D_e^s\left(E_k^t,Y_k^t,C_k^t\right)\right]^{-1}=\min\ \lambda' \\ &\text{s.t. } \sum_{k=1}^{K} z_k E_k^s \le \lambda' E_k^t, \\ &\sum_{k=1}^{K} z_k Y_k^s \ge Y_k^t+\upsilon, \\ &\sum_{k=1}^{K} z_k C_k^s = C_k^t+\psi, \\ &z_k \ge 0,\quad k=1,...,K \\ &s,t\in\{0,T\} \text{ and } s\ne t \end{aligned} \tag{5}$$

The appendix shows the decomposition results of the change in aggregated CO_2 emissions. We found the potential carbon factor change (PCFCH) of Chongqing is only less than one, while the PCFCH of other provinces is greater than one. It shows that increase of CO_2 emissions technical efficiency for most provinces in China will result from a larger carbon factor change. Different from the above results, the potential energy intensity change component (PEICH) of most provinces is less than one except Hainan, Yunnan and Qinghai. In addition, we found that the CO_2 emissions technical efficiency change (CEEFCH) is lower than the energy usage technical efficiency change (EUEFCH) for most provinces. The result shows that the China has better energy usage technical efficiency over time. Nevertheless, the technological regress occurred in most Chinese provinces from 2005 to 2010 due to the carbon abatement technological change (CATECH) and the energy savings technological change (ESTECH) are less than one. The effect of GDP change (GDPCH) is the main reason to promote the increase of CO_2 emissions for all the provinces. On the other hand, the ESTECH，CATECH，CEEFCH and PEICH have the most effect on the decrease of CO_2 emissions for three regions.

Conclusion

Economic development is always the biggest driving factors of carbon dioxide emission increase, much more than any of the other factors. Therefore, it can be estimated that China’s carbon dioxide emissions will keep increasing in pace with economic growth. The potential carbon factor change is the other positive driving factors driving carbon dioxide to increase next to economic development. Low energy efficiency and technical efficiency change are unable to relieve the pressure of carbon dioxide increase, especially in the western provinces. Among the factors curbing carbon dioxide emission increase, carbon abatement technology and energy savings technology, which represent technological progress, play a significant role. Therefore, China still needs to put technological progress in the first place in the future. Additionally, improvements of carbon dioxide emission efficiency as well successfully control the rise of carbon emission.

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References

[1] Ang B W, Zhang F Q. A survey of index decomposition analysis in energy and environmental analysis. *Energy* 2000; 25: 1149-1176.

[2] Kwon T-H. Decomposition of factors determining the trend of CO_2 emissions from car travel in Great Britain(1970–2000).*Ecological Economics* 2005; 53:261-275.

[3] Zhou P, Ang BW.Decomposition of aggregate CO_2 emissions: a production-theoretical approach. *Energy Economics* 2008; 30:1054-1067.

[4] Zhang X P, Tan Y K, Tan Q L, Yuan J H. Decomposition of aggregate CO_2 emissions within a joint production framework. *Energy Economics* 2012; 34:1088-1097.

Appendix A Changes of aggregate carbon dioxide emissions and its decomposition

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
No.	CT/C0	PCFCH	PEICH	GDPCH	CEEFCH	CATECH	EUEFCH	ESTECH
Beijing	1.053	1.066	0.983	1.114	0.958	0.985	0.986	0.970
Tianjin	1.070	1.050	0.945	1.161	0.937	0.983	1.037	0.972
Hebei	1.069	1.045	0.963	1.117	0.973	0.983	1.064	0.934
Shanxi	1.084	1.005	0.974	1.112	0.991	0.983	1.102	0.926
Inner Mongolia	1.136	1.075	0.971	1.176	0.983	0.983	1.025	0.935
Liaoning	1.093	1.045	0.967	1.140	0.976	0.983	1.031	0.960
Jilin	1.076	1.075	0.948	1.149	0.953	0.983	1.030	0.953
Heilongjiang	1.075	1.036	0.973	1.120	0.977	0.983	1.017	0.976
Shanghai	1.047	1.047	0.984	1.111	0.958	0.983	1.000	0.971
Jiangsu	1.080	1.043	0.973	1.135	0.968	0.983	1.010	0.976
Zhejiang	1.062	1.045	0.970	1.119	0.965	0.983	1.010	0.977
Anhui	1.089	1.047	0.970	1.134	0.976	0.983	1.015	0.971
Fujian	1.088	1.037	0.983	1.138	0.973	0.983	1.009	0.973
Jiangxi	1.103	1.046	0.984	1.132	0.991	0.983	0.994	0.978
Shandong	1.072	1.060	0.957	1.132	0.963	0.983	1.027	0.960
Henan	1.121	1.045	0.995	1.128	1.011	0.983	1.001	0.961
Hubei	1.109	1.045	0.978	1.139	0.990	0.983	1.027	0.953
Hunan	1.082	1.033	0.959	1.140	0.966	0.983	1.051	0.960
Guangdong	1.068	1.019	0.991	1.124	1.000	0.967	1.000	0.973
Guangxi	1.126	1.038	0.991	1.139	1.006	0.983	1.005	0.967
Hainan	1.139	1.024	1.000	1.133	1.022	0.983	1.024	0.953
Chongqing	1.116	0.998	0.976	1.150	0.988	0.983	1.070	0.959
Sichuan	1.126	1.037	0.992	1.137	1.007	0.983	0.999	0.973
Guizhou	1.036	1.073	0.921	1.126	0.936	0.983	1.090	0.928
Yunnan	1.165	1.041	1.035	1.120	1.058	0.983	0.997	0.931
Shaanxi	1.121	1.046	0.981	1.148	0.993	0.983	1.014	0.962
Gansu	1.054	1.046	0.955	1.112	0.964	0.983	1.073	0.933
Qinghai	1.142	1.038	1.009	1.131	1.027	0.983	1.030	0.926
Ningxia	1.107	1.041	0.983	1.127	1.000	0.983	1.055	0.926
Xinjiang	1.100	1.019	0.995	1.106	1.011	0.983	1.056	0.934
East	1.076	1.044	0.974	1.129	0.972	0.982	1.018	0.965
Central	1.092	1.041	0.972	1.132	0.982	0.983	1.029	0.960
West	1.111	1.041	0.982	1.134	0.997	0.983	1.037	0.943